The CRUSHED STONE JOURNAL

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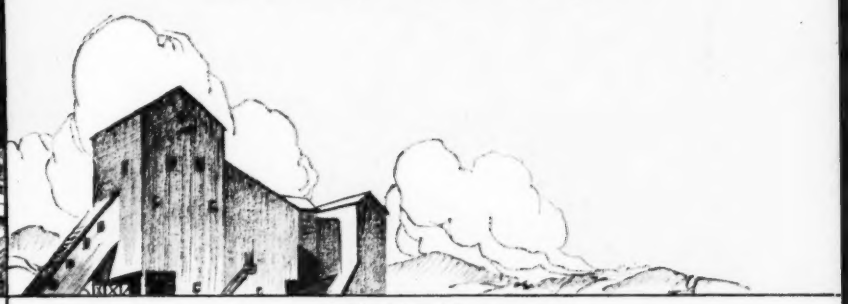
- Skid Resistance of Road Surfaces
- What Lies Ahead for Business
- Limestone Screenings and Asphalt Emulsion Stabilizer as Used in the Development of the Park System in New York City
- Future Highway Development as Related to the Crushed Stone Industry
- The Pennsylvania Turnpike



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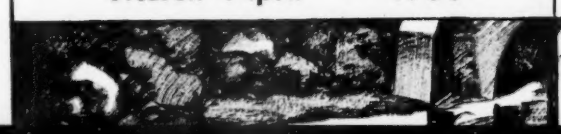

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The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

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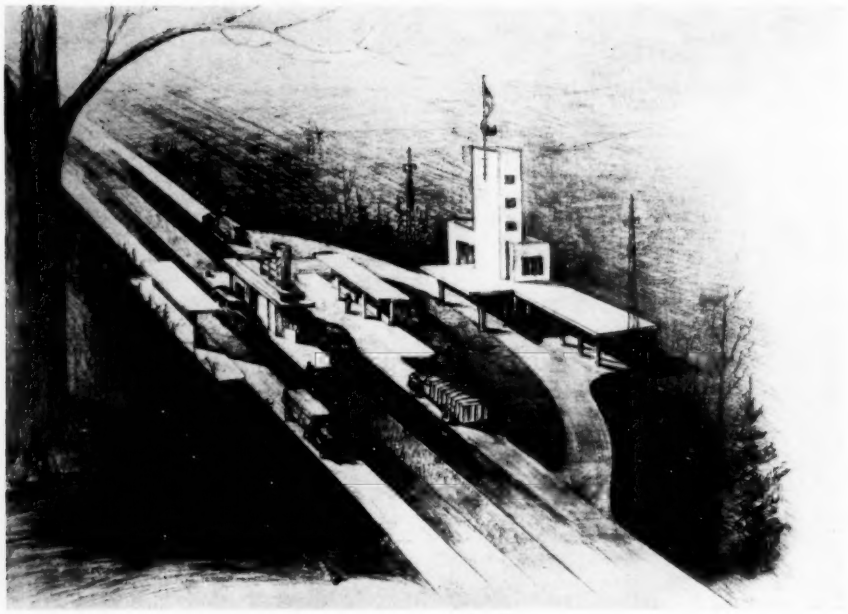

Artist's Conception of Administration Building for the Pennsylvania Turnpike Commission (see article, page 23).

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Skid Resistance of Road Surfaces[1]

By R. A. MOYER

Research Associate Professor of Highway Engineering, Iowa Engineering Experiment Station, Ames, Iowa

• **The subject of skid resistance of road surfaces is of direct interest to stone producers for it bears on the proper use of crushed stone in highway construction. Prof. Moyer, a recognized authority on skid resistance, has given in the present paper an excellent summary of the results of many of his tests.**

IT IS indeed a pleasure and a privilege to present to this group some of the more important findings in research conducted by the Iowa Engineering Experiment Station under the writer's direction, in which the skidding characteristics of various road surfaces were investigated. In this report I will give special emphasis to results of tests in which the aggregate used consisted of crushed stone or screenings, products in which all of you are vitally interested. I am particularly happy to be here today because it provides me with the opportunity to repay in part at least a debt of gratitude to two prominent members of your association. I refer to one of your former presidents who served you well, Mr. Otho M. Graves, and to your Engineering Director, Mr. A. T. Goldbeck.

Twenty years ago your esteemed Mr. Graves, who was then a college professor, left a lasting impression on your speaker who was at that time a very green freshman. That dignity and personal charm in the man, whom I am sure all of you admire, meant a great deal to me then. The fact that he could make descriptive geometry, one of the most feared and most abstract subjects in our engineering curriculum, interesting and understandable, speaks well for his ability. You are fortunate to have had so able a leader in your ranks. After these many years it has been a real pleasure to renew our friendship under such pleasant circumstances.

For more than 16 years I have followed the literature in highway engineering. During that time I have been impressed by the fine work and the type of thinking which has made the accomplishments of your Engineering Director, Mr. Goldbeck, so outstanding. Time is too short to make it possible for most of us to learn directly by experience; in fact, much that we know, we learned by borrowed experience. Mr. Goldbeck has simplified many of our highway engineering problems for me and so when he invited me to address you today, I was more than pleased to accept his kind invitation.

Origin of Skid Tests

Now coming back to the main subject of my paper, that of developing non-skid roads, you may be interested to know that tests to determine the slipperiness of road surfaces were conducted by the Iowa Engineering Experiment Station under the direction of Dean Agg as early as 1924. Since 1932, an intensive study of many phases of the problem has been conducted under the direction of the writer. Road tests have been run on many surfaces and surface conditions, to determine the extent of the slippery condition, the probable causes, and the most satisfac-

[1] Presented at the Twenty-Second Annual Convention of the National Crushed Stone Association held at the Netherland Plaza Hotel, Cincinnati, Ohio, January 30, 31 and February 1, 1939.

tory methods for correcting this condition. Accident statistics have been studied. The frictional requirements when braking and when driving on curves have been studied. The variable effects due to the condition of the tires, the load, the type of wheel suspension and the speed of the car have also been studied. Interest on the part of engineers in developing non-skid road surfaces has been increasing steadily during recent years because (1) many serious accidents have been reported as definitely due to slippery road surfaces, (2) the demand for operating in safety at high speeds has stimulated the construction of non-skid surfaces, and (3) the development of many new types of surfaces, particularly of the bituminous types known to be slippery if not properly constructed, has also added to this interest. Nevertheless, since the majority of highway accidents are charged to the carelessness of the driver and so few to defects of the road, the real value of developing non-skid roads is not always appreciated by the public or even by all highway engineers. Just because cars do not always skid by sliding end for end or broadside over the road is no reason why such roads may not be considered as slippery. A non-skid surface will not only reduce the tendency to skid in this extreme way but what is probably more important, but less evident, it will permit the driver to stop the car in far shorter stopping distances, to make sharper turns, and to maneuver the car with a far greater margin of safety than on a slippery surface.

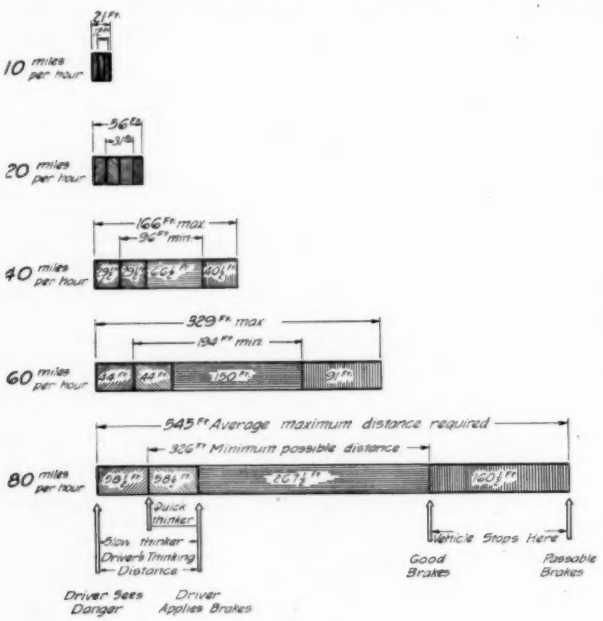


FIGURE 1

STOPPING DISTANCES. SAFE SPEEDS SHOULD PROVIDE FOR A FACTOR OF SAFETY IN STOPPING AND SHOULD BE BASED ON THE AVERAGE MAXIMUM STOPPING DISTANCE REQUIRED AND NOT ON THE MINIMUM POSSIBLE DISTANCE. (ARRANGEMENT ADAPTED FROM PUBLIC SAFETY, JULY, 1935)

Statistics collected and published by the Travelers Insurance Company indicate that about 1,500 persons are killed annually and 38,000 are injured in the United States in skidding accidents, and that an additional 6,000 are killed and more than 100,000 are injured in accidents in which the car is out of control, in many cases, no doubt, because the surface is slippery or at least not as non-skid as it might be. These data show quite definitely that slippery surfaces are the cause of many accidents, and since we also know that this slippery condition is the result of improper construction and maintenance, we would like to call to the engineer's attention his obligation to correct the slippery condition as soon as possible.

Methods of Conducting Tests

Before presenting some of the more important details concerning the design features and corrective measures to be adopted to build skid resistance into the more common surfaces of today, a brief discussion of the methods of conducting the road tests, and some general observations made by the writer in connection with these tests may be helpful in obtaining a clearer understanding of the problem.

Tests were conducted using a two-wheel trailer test unit equipped with either new tread or smooth tread tires and an integrating dynamometer specially designed to measure the skidding forces. Since the wet condition creates the most common hazardous condition, a water tank was placed on the tow truck to sprinkle the road when running the wet tests.

The resistance to skidding which a given surface can provide is best expressed in terms of the coefficient of friction which is the ratio of the force causing the tires to skid to the load on the tires. If a large force is required to cause skidding, the coefficient is large; if the force is small, the coefficient is small. The tests indicated that practically all roads in the dry condition can provide friction with a liberal amount to spare for the ordinary driving demands and even for the demands when an emergency arises. Many surfaces in the wet condition were found to be almost as safe as in the dry condition, but the tests indicated that there are many surfaces

which are dangerously slippery when wet. The surfaces which were found to be most slippery when wet were the bituminous types glazed with a coating of surplus oil, asphalt, or tar. Surfaces covered with snow, ice, or mud were also found to be very slippery. The latter is not a characteristic of the road surface, but a condition which must be corrected by proper maintenance, as will be shown later.

Effect of Speed on Skidding

In the early work on skidding, tests were conducted at low rates of speed at which the large uniform tractive forces required of the towing vehicle could easily be provided. In the more recent work, the variable effect due to speeds ranging from 3 to 40 miles an hour was investigated. In certain respects, the results were almost startling, because they indicated for the first time how slippery certain surfaces or surface conditions really are. On certain surfaces in the wet condition it was found that at 40 miles an hour the friction available was only one-fourth to one-fifth as great as at 10 miles an hour. In fact, under certain conditions these surfaces were found to be equally as slippery as snow- or ice-covered surfaces. As was previously stated, the frictional resistance which can be developed by a rubber tire on a dry, hard and firm surface is considerably greater than is required for ordinary or even for emergency driving operations. It is the wet condition, or the presence of excess oil, mud, snow, ice, or of loose sand or gravel or wet leaves on the surface which makes the road slippery. The wet condition is the most common cause of slipperiness, and provides surfaces with the widest range in frictional resistance, hence the greatest uncertainty to the driver in regard to what he may expect with surfaces in this condition.

In theory and as evidenced by our tests, the total frictional resistance to skidding is equal to the true frictional resistance between the two surfaces, plus the resistance which results from a mechanical interlocking of the tire tread with the road surface. This mechanical resistance is brought about by the minute particles of rubber interlocking with equally small projections in the road surface which cause the rubber to shear off as the tire slides over the surface, in extreme cases leaving the debris of rubber in its path, commonly known as the skid marks. The true frictional resistance is theoretically proportional to the normal load supported by the tire. The mechanical resistance, however, is dependent not only on the normal force or load on the tire but depends also on the area of contact of the tire with the road surface. Surfaces which are smooth, which provide a large contact area for the tire and close and intimate contact should, as indicated by our tests, provide the greatest frictional resistance against skidding. Conversely, surfaces which have a rough knobby surface texture do not provide the intimate contact and

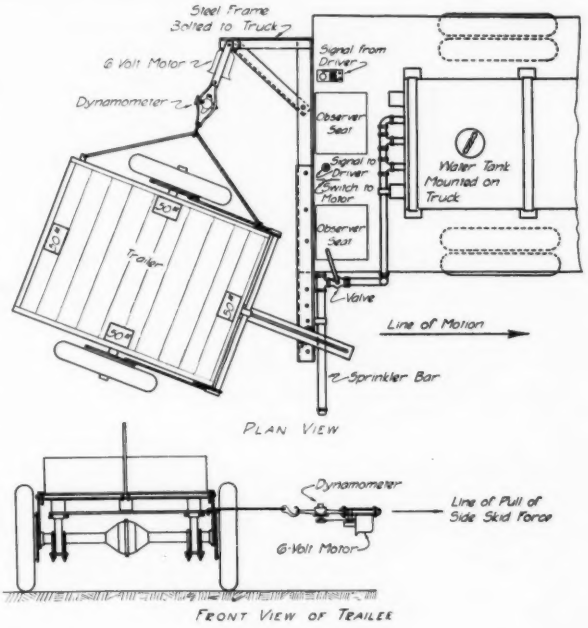


FIGURE 2

ARRANGEMENT OF TEST EQUIPMENT USED FOR DETERMINING THE COEFFICIENT OF FRICTION OF TIRES ON ROAD SURFACES WHEN SKIDDING SIDEWAYS.

therefore do not provide the equally large frictional resistance provided by smooth surfaces with a gritty finish.

Effects of Wet Surfaces

On wet surfaces, the water serves as a lubricant, unless it can be squeezed or squeegeed from the surface as the tire rolls over it. This squeezing and squeegee action is very effectively carried out at slow speeds even when "bald-headed" or smooth-tread tires are used. At speeds above 20 or 30 miles an hour, the tires fairly skim over the surface, and it is far more difficult to remove the excess water and to eliminate the lubricating effect of the water. If the water is trapped between the tire and the road, skidding resistance drops off sharply. On wet surfaces, it is important to recognize that a large area of intimate contact is necessary to develop high fric-

tional resistance; that small grooves must be provided in the road and in the tire to permit the excess water to escape; and that the aggregate on the surface must be hard and sharp with many small points of contact to grip the tire and prevent skidding. Tests conducted by the writer indicated that surfaces with a sandpaper-like finish provided greater frictional resistance when wet than surfaces on which large-sized aggregate was used to develop a rough-knobby finish. Surfaces with a hard silica sand, quartzite, trap, or similar hard aggregate were more satisfactory than surfaces on which soft limestone or other soft, highly absorptive aggregate was used. It did not seem possible to squeeze out the water as effectively on surfaces on which soft and highly absorptive aggregate was used as where hard impervious aggregate was used. Furthermore, it may also be said that to reduce slipperiness for any purpose, hard abrasive material, such as carborundum or a sharp sand, generally will be more effective than a soft limestone, shale, or the like.

Another important characteristic of surfaces revealed by the tests was that surfaces which were

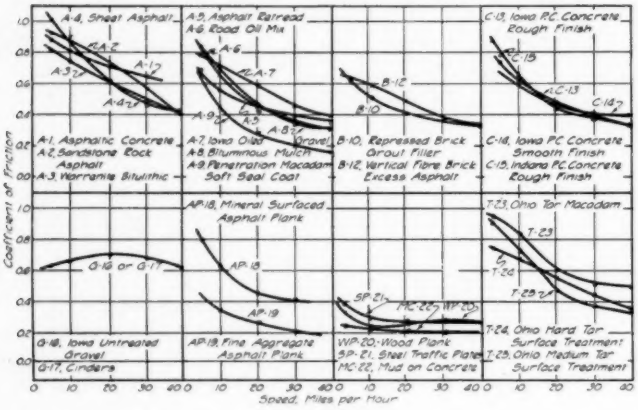

A-4, Sheet Asphalt
A-5, Asphalt Retread
A-6, Road Oil Mix
C-13, Iowa P.C. Concrete Rough Finish
A-1, Asphaltic Concrete
A-2, Sandstone Rock Asphalt
A-3, Warrenite Bitulithic
A-7, Iowa Oiled Gravel
A-8, Bituminous Mulch
A-9, Penetration Macadam Soft Seal Coat
B-10, Depressed Brick Grout Filler
B-12, Vertical Fibre Brick Excess Asphalt
C-18, Iowa P.C. Concrete Smooth Finish
C-15, Indiana P.C. Concrete Rough Finish
AP-18, Mineral Surfaced Asphalt Plank
T-23, Ohio Tar Macadam
G-16 or G-17
AP-19
SP-21
MC-22, WP-20
G-16, Iowa Untreated Gravel
G-17, Cinders
AP-19, Fine Aggregate Asphalt Plank
WP-20, Wood Plank
SP-21, Steel Traffic Plate
MC-22, Mud on Concrete
T-24, Ohio Hard Tar Surface Treatment
T-25, Ohio Medium Tar Surface Treatment
Coefficient of Friction
Speed, Miles per Hour

FIGURE 3
TYPICAL RESULTS OF SKID TESTS ON VARIOUS WET SURFACES

highly polished or glazed were quite certain to be dangerously slippery when wet. Presumably on a highly polished or glazed surface, such as on a smooth steel plate, a steel troweled or highly polished concrete surface, or a glazed-over asphalt surface, the water is trapped between the tire and the road surface and cannot be squeezed out as effectively as on a somewhat rougher textured surface which has the sandpaper-like or gritty surface finish.

In view of these general observations concerning the skidding properties of road surfaces, let us now examine the more important surfaces in general use today, such as portland cement concrete, the bituminous types, asphalt plank, mud-, snow-, and ice-covered surfaces, and snow- and ice-covered surfaces treated with cinders or screenings.

Portland Cement Concrete Surfaces

The portland cement concrete surfaces provide the largest mileage of a uniform standard of construction among all the high-type surfaces used in this country today. The skidding properties of portland cement concrete were found to be the most consistent of all the surfaces on which tests were run. While the skidding resistance was not as high on the wet portland cement concrete as on certain bituminous types, the driver has the assurance of moderately high resistance to skidding, and he knows by experience just about how much he can depend on the wet portland cement concrete to protect him. In recent years, the demands for greater frictional resistance required at the higher speeds make it desirable to build the greatest possible skid-resistance into all surfaces. In the case of portland cement concrete surfaces, this may be accomplished by brooming the surface or by finishing it with a canvas belt.

In a survey conducted by the writer as chairman of the project committee of the American Road Builders' Association on this subject, it was found that more than one-half of the state highway departments and many city departments now specify brooming for the final finish on portland cement concrete pavements. The brooming or belting operation should bring the sharp sand grains to the surface and should remove or break up the coating of cement paste which is responsible for the slippery condition which is certain to develop on portland cement concrete surfaces finished with a steel trowel. The cement paste develops a hard surface finish which is polished smooth by the wearing action of traffic. Such a surface absorbs water easily and it does not appear possible to squeeze out the excess water readily nor does it have the grittiness of concrete surfaces finished with a broom. The use of a liberal amount of clean, sharp, hard sand in the mix, even leaning toward an oversanded mix, should improve the skid resistance of portland cement concrete. Excessive manipulation, vibration, or finishing draws an excess of cement paste to the surface and is certain to contribute to the slipperiness of surfaces so constructed. Portland cement concrete surfaces rarely become dangerously slippery, when wet. However, if they do, the most effective treatment is to cover such sur-

faces with a bituminous mat 1 inch to 2 inches thick, and of a type known to have a high skid resistance, as will be described later.

The wear on a high-quality portland cement concrete surface caused by traffic is very small, and since the hydrated cement paste has a hardness or wearing resistance approaching that of the aggregate, concrete surfaces are likely to lose some of their grittiness with age. Proper brooming will prolong the high skid-resistance present on the new concrete surfaces. The application on the surface of the green concrete of corundum, carborundum, or emery recrush or gannister or similar abrasives which are considerably harder and more wear resisting than the cement or aggregate, provides a method of treatment which is known to be very effective on concrete stairways and offers a possibility in building a more permanent skid-resistance into our portland cement concrete roadways.

Bituminous Surfaces

Tests on bituminous road surfaces provided the largest variation in frictional resistance found on any of the surfaces tested. These surfaces, popularly known as "black-top," are generally thought of as dangerously slippery when wet. The results of skid tests on several bituminous surfaces substantiated this belief. However, the tests on the majority of bituminous surfaces in the wet condition provided frictional resistance appreciably higher than that obtained on any other type of surface tested. It can now be said without fear of contradiction that it is possible to build "black-top" surfaces which are as free from the dangers of skidding as any road surface in common use today. Furthermore, with the information now at hand, there is no reason why every mile of bituminous road cannot be made reasonably safe from the hazards of skidding.

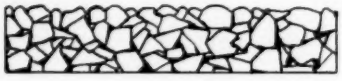
An examination of the bituminous surfaces found to be slippery revealed that they were covered with heavy seal coats of an excess of bituminous material. The surfaces which offered high resistance to skidding were covered with sharp, hard sand, or with hard and finely crushed rock particles, held in place by the weaker bituminous cement. As the tops of the sand or rock particles were uncoated with bitumen, these surfaces may be said to have a sandpaper-like finish, renewable under the action of traffic and weathering. It should be recognized that excess tar or asphalt in a bituminous mixture is not only certain to cause a slippery surface in hot weather but is also likely to cause the surface to be unstable and to creep or shove and to form ruts under the action of traffic. The use of certain emulsions or cutbacks of the slow, medium, or rapid curing type appear to cover the aggregate in thinner and stronger films than if straight oil asphalts or asphalt cements are used. These thin films wear off faster, especially on hard, non-absorptive aggregate, than the thicker films obtained in the use of the heavier oil asphalts, and therefore emulsions and cut-backs can be expected to develop a higher skid-resistance than oil asphalts and asphalt cements.

Various trips by the writer during the past two years, covering about 6,000 miles of bituminous surfaces in both the Eastern and Western States, revealed that the application of a plain seal coat on some of the bituminous surfaces was the most common cause of the slippery condition observed on possibly 1,000 miles of road, and that the surfaces which appeared to be non-skid were constructed without seal coats or with seal coats liberally covered with crushed rock chips and clean screenings. The use of a dense graded mix or of fine graded aggregate for cover material seemed to provide the water-tightness which is necessary in regions where freezing and thawing may cause disintegration of surfaces not so protected. Where seal coats are used to provide a watertight, non-skid, wear-resistant surface, the survey referred to above revealed that the application of 0.2 gallon per square yard of a cutback asphalt or a quick-setting emulsion was immediately followed by spreading 35 pounds per square yard of aggregate three-eighths inch to 40-mesh size with a mechanical spreader. The aggregate was brushed evenly over the surface and rolled with a three-wheel 10-ton roller. In the city of St. Louis, 1,800,000 square yards of anti-skid surfacing has been placed. A large part of this work was done at intersections and at each approach 150 feet back from the intersection. The director of streets, Mr. McDevitt, reports that accidents at intersections so treated have been reduced approximately 50 per cent.

Bituminous surfaces which are glazed over with excess asphalt and which are known to be slippery may be improved by scarifying the surface and by applying screenings or rock chips uniformly over the surface, which is heated either by the sun or by a heater, honing or planing it with a blade, and finally rolling the surface with a moderately heavy roller. Another possibility is that of cutting back the excess asphalt with a volatile solvent, such as kerosene or a fuel-oil distillate, then applying gritty cover material to blot up the excess binder and again rolling it.

While limestone dust and powdered asphalt are very effective in drying an oily surface or in blotting up the excess asphalt and in stabilizing the surface, they lack the grittiness which sand or the coarser screenings and rock chips can give the surface to make it highly skid-resistant. The limestone screenings, or rock dust, or powdered asphalt should only be used in combination with the abrasive aggregate

Open Graded
HEAVY SEAL COAT—NO COVER STONE
SURFACE COVERED WITH EXCESS ASPHALT. VERY SLIPPERY WHEN WET. PROLONGS ROAD LIFE BUT JEOPARDIZES HUMAN LIVES



Open Graded
NO SEAL COAT
ROUGH KNOBBY SURFACE FINISH. MODERATELY NON-SKID WHEN WET. CREATES AN UNPLEASANT RUMBLING NOISE WHEN DRIVING OVER IT.

FIGURE 4

required to make the surface non-skid. If a large excess of asphalt is present, greater effort is necessary to blot up this excess by using rock dust and powdered asphalt. As stated previously, the use of large stones will develop a surface with a rough-knobby finish which, on a glazed asphalt, is not as permanent and as satisfactory as the treatment providing a gritty sandpaper finish.

Miscellaneous Types

Certain surfaces, such as wood plank, smooth steel traffic plates, and ordinary asphalt plank, were found by test to be as slippery when wet as icy surfaces. These materials are generally used on bridge floors, where skidding accidents are far more dangerous because of the restricted roadway. They are so slippery that they should not be used under any conditions on our highways unless they are provided with some type of gritty surface finish. The wood plank may be covered with a bituminous treatment and the use of suitable stone cover material. The steel traffic plates should have a stud or grid design providing sharp edges which will grip the tire and prevent skidding. The surface of the ordinary asphalt plank should be covered with sharp, gritty aggregate which may be rolled or pressed into the plank to form a rough-textured gritty finish.

Unstabilized Surfaces

Crushed stone, or macadam surfaces can provide a uniformly high resistance to skidding in the wet or dry condition, provided the surface is firm and reasonably free from loose material. Loose rock particles act as ball bearings under the tires, causing variations in the skidding resistance which makes it difficult to steer and is, therefore, responsible for many accidents. These surfaces should be stabilized with clay or oil or with a similar type of binder which will prevent the loose condition. The loose condition creates another serious hazard—the dust hazard, which interferes with visibility. It also increases the cost of transportation in the form of increased fuel, tire, car repair costs, and road maintenance costs to more than justify the cost of stabilizing the surface. Engineers and road officials should realize that untreated surfaces are expensive, dangerous, and take much of the pleasure out of driving for the present-day motorist.

Dense Graded
NO SEAL COAT
"SAND-PAPER" FINISH USING HARD ABRASIVE AGGREGATE. PROVIDES EXCELLENT NON-SKID SURFACE WHEN WET. CONTINUALLY RENEWABLE UNDER TRAFFIC IF PROPER GRADE AND AMOUNT OF ASPHALT OR TAR IS USED.

Open Graded *Dense Graded*
SEAL COAT WITH FINE GRITTY AGGREGATE COVER
A GRITTY SURFACE FINISH USING ⅜ INCH TO 30 MESH SCREENINGS AND CRUSHED STONE AGGREGATE AS COVER MATERIAL. EXCELLENT NON-SKID SURFACE WHEN WET.

FIGURE 5

Ice Surfaces

The results of tests on mud-, snow-, and ice-covered surfaces clearly indicated that they constitute the most uniformly hazardous road conditions which the motorist is likely to encounter. Ice and sleet were found to be particularly slippery, providing a frictional resistance only about one-tenth as great as that provided by a dry concrete surface. A driver venturing out on a freshly formed icy surface with a car not equipped with tire chains is inviting all kinds of trouble. The crown of the average city

street introduces enough slope to cause the car to slide into the curb unless the driver can straddle the crown line. The car cannot climb a long grade steeper than 3 or 4 per cent, and will be very likely to slide down, completely out of control, on grades steeper than 5 per cent. The seriousness of the snow and ice problems as related to skidding is indicated by the fact that about 80 per cent of all skidding accidents in Iowa, for example, were found to occur in the four winter months. The correction of this slippery condition is clearly a maintenance problem and demands prompt attention, if it is to be effective.

Ice forms at temperatures close to the freezing temperature and if sand or cinders or screenings are applied on the surface promptly at this time, they will be embedded in the ice, thereby raising its frictional resistance three or four times that which it can provide without such treatment. If the application of the abrasive material is postponed until much lower temperatures prevail, it will not be imbedded into the ice, and the wind and traffic will whip it off the road. If the stock piles of the abrasive material are treated with a solution of calcium or sodium chloride, using 50 pounds of the chloride per cubic yard, imbedding of the material so treated may be accomplished at temperatures considerably below freezing.

Snow Surfaces

Snow, especially dry snow, has two to three times the skid-resistance obtainable on ice. However, the transition from snow to ice may be made so easily that the driver has no assurance that the snowy surface is free from ice. For this reason, maintenance men should lose no time in removing the snow from the pavement or in applying abrasive material at all intersections, on hills, and on curves as soon as the snow becomes packed. Traffic will assist in the imbedding process, and if the temperature is close to the freezing point where the snow is likely to change to ice in the traffic lanes, the prompt application of the material before this transition takes place will make its imbedding into the surface more satisfactory. Dark abrasives are imbedded more readily when the sun shines than the lighter colored abrasives, because they absorb the heat of the sun. Scraping the dry packed frozen snow from the pavement is frequently possible, and this is a very effective treatment. With the increased travel during the winter and the increased demand for all-weather highway transportation service which is evident today, maintenance engineers must plan to act promptly to meet the emergency slippery road conditions created by ice and snow, if skidding accidents from this source are to be eliminated.

Mud on Road Surfaces

A skidding menace which is the cause of many accidents on rural pavements is the presence of mud

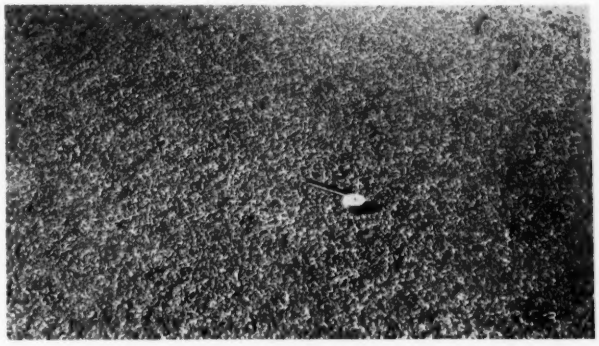


FIGURE 6

A TYPICAL NON-SKID SURFACE FINISH AS DEVELOPED BY THE CALIFORNIA HIGHWAY DEPARTMENT. THE USE OF SCREENINGS OF THIS SIZE MAKES AN EFFECTIVE NON-SKID COVER WITH MATERIAL WHICH WILL NOT BE KICKED OUT READILY BY TRAFFIC.

on pavements. The mud is either splashed on the pavement from the shoulder when a car runs into the rut which frequently forms adjacent to the pavement, or when the car runs out on the shoulder, or it is tracked onto the pavement from muddy side roads, farm drives, or field entrances. On important roads, the writer recommends that the shoulders of these roads be surfaced with gravel, cinders, or crushed rock for a width of 8 or 10 feet. Not only would the mud hazard be eliminated in this way, but shoulders could then be used to good advantage as traffic lanes when ice or sleet is forming on the pavement. The tracking of mud onto the road at intersections can be prevented by surfacing all these approaches with gravel, sand, or crushed stone for a distance of 50 or more feet from the pavement.

In the questionnaire sent out by the writer for the Safe Roadways Committee of the American Road Builders' Association to all State highway departments and 90 city street departments, one of the questions called for a statement in regard to the mileage of roads and streets under their jurisdiction which each department considered to be safe from the hazard of skidding. The answers to this question were generally indefinite, because the engineers had no factual basis for giving a definite answer. The only way by which the slipperiness of a road sur-

(*Continued on page 26*)

What Lies Ahead for Business[1]

By H. GORDON HAYES

Professor of Economics, Ohio State University, Columbus, Ohio

• To what extent the business cycle will continue on the up-swing is, according to Prof. Hayes, dependent upon a number of factors, some favorable, others unfavorable. Prof. Hayes has keenly analyzed the various elements of the present economic situation and his conclusions should prove of unusual interest.

I AM mindful as I think of this problem, of the problem that has faced the human race since we first climbed down out of the trees, and that is the problem of the future. You will recall the Biblical stories of the dreams, and particularly, of course, of Joseph who interpreted the dreams and who saw seven fat years and then seven lean years ahead of Pharaoh. And then of course all through history we had the astrologers, the crystal gazers, and the tea-leaf counters, and I understand that in these United States today there is a very thriving business in this matter of forecasting the future. If some of the statistics are to be believed—and I hope they are not—we would expect that out of a group of business men such as this, there would be some who would from time to time feel that it was worth while to put a little money on the barrel head in order to have someone tell them what was around the corner.

I recall the summer of 1930—and I have a special way of dating that which I don't need to go into here—and I recall that Colonel Leonard Ayres of Cleveland, with his Cleveland Trust Company Bulletin which he gets out on the 15th of each month, and which some of you undoubtedly read, stated in the August issue of 1930 that the depression was over, and he proved it by the fact that all his various curves had a little turn-up to them in August as compared with the previous month.

Well, he wasn't right about that, and I recall hearing one of my good friends and former teachers make a speech to a bond club in Columbus in the summer of 1931, and he said at that time that we were out of the woods and he anticipated that the Federal Reserve Index would rise by five to seven points within the next two or three months. The Federal index, the index of mining and manufacturing production, was then at 86, and within three months it was at 76. It went down ten points instead of rising some six or seven as he anticipated.

And then of course we have also the recent experience of '36 and the early part of '37, when so many folks thought we were headed for permanently good times, instead we got this recession or depression which began in August of 1937, in which business fell more quickly and more sharply than it ever had in our history. In some fifteen weeks the business indexes fell off as much as they had fallen off in fifteen months beginning with the latter part of 1929.

And so I suggest that out of my experience, gentlemen, I must be pretty cautious in regard to attempting to foretell the future, and if that is the package of goods that you all wanted me to sell, we just ought to quit right now and I would submit this sample that I have given to you and then we might turn to some other line of business.

What we might do, I think, gentlemen, is to note certain favorable factors that it seems to me lie ahead, and also certain unfavorable factors, and then after I have finished with that, I want to say something about the twentieth century as compared with the nineteenth century, and you are going to find that interesting.

In regard to the favorable situations, I will call your attention to the banking situation which I think is in very sound condition. Certainly the situation is altogether different from what it was in '30, '31 and '32. Here we have the member banks of the Federal Reserve System with something more than three billion dollars of excess reserves with the twelve Federal Reserve Banks, and you know that that means that the banks of the country could increase their deposits through increasing loans by something like ten times. That is, that gives a possible expansion in our banking business of some thirty billion dollars, if the banks should all begin to do it at about the same time.

[1] Presented at the Twenty-Second Annual Convention of the National Crushed Stone Association held at the Netherland Plaza Hotel, Cincinnati, Ohio, January 30, 31 and February 1, 1939.

If anybody wants gold as a basis for banking expansion, we have certainly got that, because we have some fourteen and two-thirds billion dollars of gold, most of it buried down to the south of us here. During this year we have gotten into this country something like one and a half billion dollars of this heavy yellow metal.

Furthermore, we have deposit insurance of the banks and that in itself, I think, is a very fine safety factor by way of delaying runs upon banks such as we experienced in the latter part of '32 and the early part of 1933.

Then I take it from what little I can find out about it that the inventory situation is better than it has been at some times. Inventories are down somewhat. Department store inventories are down something like ten points, from 86 to 76 on the basis of 1923, '24 and '25, from November '37 to November '38, and that is undoubtedly a favorable sign.

Furthermore, we are told in all the papers that there is a good year ahead so far as building is concerned. Of course, almost all persons who have anything to say about the future are very optimistic about it, and folks do seem to be optimistic about the building business, as of course they have been optimistic in the past several years about the building business. But at the present time the indexes for building are considerably higher than they were last year at this time, and considerably higher than many of the indexes have been at any time since '32.

So far as public construction is concerned, there was more of that in the last quarter of last year than at any preceding time in our history. You possibly recall that building of residences almost disappeared during the deepest days of the depression. In the early part of 1933 the January, February and March index stood at 8 on the basis of 1923, '24 and '25 being 100, and from 8 it rose to 54 a year ago November, and to some 76 this past November, those figures being adjusted for seasonal variation.

In the third place, it seems to me that when we notice what happened in general during the fourth quarter of this past year, we find considerable ground for encouragement. Take, for example, automobiles. During the first nine months of the year we produced fewer automobiles than any other year since 1929, with the exception of 1932, and then during the last three months of the year we produced approximately as many automobiles as we have ever done during those last three months of the year. Of course, we produced more than we used to produce even in good years because of the change with respect to the coming out of the new models, but we did as well as in the preceding two or three years since this change has been made.

Then if we look at the index of industrial production of the Federal Reserve Board we will find that last May it stood at 76, and in November at 103, and in December it was still a little higher, and that, gentlemen, is a very big increase. It means an increase of one-third. From 75 to 100 would be one-third. It means a little more than one-third.

When we look at the matter of income payments which are figured by the Department of Commerce, we find that the income payments, that is the wages, dividends, etc., that folks receive, were better in the latter part of this year than they have been at any time during the year, and that, too, is adjusted for seasonal variation. Indeed, December was the best month of the year, adjusted for seasonal variation, on the basis of income payments.

Now I am running into stormy weather, but it seems to me, too, that so far as political factors are concerned, there ought to be more promise so far as the business outlook is concerned. I understand that not all of you folks are enthusiastic supporters of President Roosevelt. Some of you are not. As I understand it, President Roosevelt feels that his reform program is ended for the present, anyway, and that should induce a generally better feeling so far as business is concerned. Furthermore, as I understand it, there isn't contemplated that there should be an increase in taxation, and of course that also would commonly, I take it, be regarded by business men as a not unfavorable factor.

In the last place—and I must come back to this again later—it seems to me that we can rather confidently expect that for the next quarter, or during this entire next year government spending will continue at a pretty high rate, and I list that now, gentlemen, as a favorable factor rather than as an unfavorable factor. When some of you think about the public roads program, possibly you are not downhearted to think that government expenditures may continue in the road business.

I have suggested several things which I think are favorable in respect to the immediate business outlook. On the other hand, as we professors always say, I want to consider some of the unfavorable factors, and one of these unfavorable factors is the matter of capital investment. There doesn't seem to be much promise ahead for big capital investments. We have the money, we have the banks with these three billion dollars of excess reserves to which

I called attention a while ago, we have a lot of idle money, and if we could get under way a big capital building program it undoubtedly would be one of the finest things that could happen to business, but now for reasons which I shall develop a little more fully later, it seems to me that we can't expect a great deal in respect to this particular phase of our general economy.

In the second place, we have the matter of the railways, and I should say that the condition in which the railways find themselves is an unfavorable factor. The railways are short of equipment. They would do well to have improvements in cars, in engines and in track, but they are in a very bad shape financially. Out of some $24,000,000,000 of capitalization, we find railway debts of some $14,000,000,000. They are all loaded down to the gunwhales with debt and they find it difficult to borrow money with which to go ahead.

Furthermore, they find themselves being subjected to very keen competition with trucks and with pipelines, and with automobiles generally in respect to passenger traffic, and they seem to feel that the thing to do whenever they find traffic falling off is to raise their rates. It would seem to me that if a fellow is finding it difficult to sell the thing he has to sell, he might find it advisable to cut prices rather than raise them. If we could do something about the railway business, that undoubtedly would help us in the matter of our general economy.

In the matter of the building program which I listed as a favorable factor, there is an unfavorable aspect of that, and that is a high building cost. The Bureau of Labor Statistics in the Department of Labor at Washington shows for the most recent months that I have seen, an index for building materials prices wholesale of 89 on the basis of 100 for 1926, and the index for all the commodities in this index is only 77, and within that building material index steel, for example, stands at 107.

Now whatever the cause of it, and however justifiable it may be to have those prices, I don't think there is any question that having those prices tends to delay the building expansions that we otherwise might have.

There is another very important thing, and that is the matter of population. The American people have long experienced a very rapid increase in population, but that increase in population is almost over. The population is still increasing, but it is increasing at a very decidely decreasing rate and it will not be very long until the population, according to present trends, will stop growing, and indeed will begin to decrease. That undoubtedly poses very serious problems for business in the long run.

The fifth unfavorable factor that I will call to your attention is the matter of foreign trade. What we need, of course, is to have a great expansion in our foreign trade. We need to be back selling something more than $5,000,000,000 worth of stuff abroad every year, such as we did in the latter part of the 1920's, but now we are selling only about half that much stuff. Last year we had a good year so far as the export balance was concerned since we had a balance of 1.1 billion dollars, that is we sold 1.1 billion dollars more than we bought; and incidentally, one explanation of that is the bringing in of something more then one billion dollars of gold. That is one way in which we got paid for the excess of exports which we had.

The welfare of our agricultural group is very vital to business, and they find themselves greatly handicapped as compared with anything in past history because of this matter of the closing of foreign markets with respect to argicultural produce. You possibly have noticed the figures about the wheat crop in the world which is something over five billion bushels this year, and the four big nations of the world that export wheat, United States, Canada, Australia and the Argentine, have something more than one and a half billion bushels of wheat for export. The ungrateful countries to which we wish to ship it want to take in only about half of this amount which is available for export.

Incidentally, gentlemen, it is interesting to think of the prayers which men have made all through the centuries: "O Lord, give us this day our daily bread," and then to find that when the Lord has finally answered this prayer, we find that it is a great nuisance to us, causing us to bog down into a very serious economic situation. There is too, the problem of the cotton which we have in such tremendous abundance. We have trouble getting the foreign nations to buy that.

The various foreign nations with their high protective tariffs, as they gird themselves about the loins for the war which seems to be somewhere in the future, make a very unfavorable condition so far as the expansion of our foreign trade is concerned. Mr. Hull's trade agreements are working in the right direction, but after all, I think this is only something of a little drop in the bucket.

Then, too, of course, one other unfavorable thing is the possibility of war. If the gods that be do push us

toward a war that means one thing for business as compared to what we would have if it were not for that.

If you will keep in mind these so-called favorable factors and the so-called unfavorable factors, I want to throw some of these against the general background of the twentieth century and the nineteenth century. One very important point I want to make, gentlemen, is that the twentieth century is not the nineteenth century; but I also want to make this point, that what you and I have in the tops of our heads is almost wholly nineteenth century. For me to say that, and for you to reflect on it, may be the best thing, if there are any good things, about this speech of mine this afternoon.

Here we find ourselves in a new century. What do I mean when I say the twentieth century is different from the nineteenth? I mean that our problems, their general background, and the methods by which they must be handled are different from those of the past century. The nineteenth century was marvelous. Think of 1800. What kind of agricultural methods were we using? We were using the kinds that were old in the time of Jesus. There had been practically no change in all those centuries. How were we making our textile goods? Again we were making them by methods that were old in the time of Jesus. There had been practically no change in all those years.

Think of George Washington and George Washington's army. What better means of communication did he have between his different armies than Julius Caesar had? What better wagons did Washington have than Caesar? He may have had slightly better wagons, but I guess there is no question but that Caesar had better roads than Washington had. Possibly, too, the horses in Caesar's time were as fast as the horses in Washington's time. And of course Washington had better guns than Caesar had, we had gotten gun powder during that time. The changes between that time and 1800 were relatively small.

And then think of the power that we unleashed. Think of the steam engine on the rivers and the oceans and on the iron rails, think of the telegraph and of the telephone and structural steel, and electricity and the street car and the interurban, plate glass—tremendous, tremendous! The only thing I can think of that we were already wise enough to provide ourselves with in 1800 is crushed stone. We already had that, and of course a great advance was made when man caught onto that.

In the nineteenth century, then, we had this tremendous expansion. During one of the decades here in this country we built 75,000 miles of railroads; enough track to go around the world three times in ten years!

And then what happened to population? Population doubled from 1800 to 1900. In all the years of human life on this continent the population of the world had been finally gotten up to something less than a billion in 1800, and then in the short space of 100 years we added as many more people as had been added in all of the time up until 1800. If you take 150 years in there, we tripled it. That is amazing, thoroughly amazing.

Also, of course, during the nineteenth century we had what I like to call the free market. That doesn't mean that things were free. It means that buying and selling were free. We had hardly anything in the way of price controls; we didn't have a wage and hour bill such as you fellows were wrestling with this morning; prices were set in open competitive markets; we didn't have public utilities and public utility regulations; we didn't have government control of this and government control of that. We had a free market.

Now where are we, gentlemen, in this decade, the fourth decade of the twentieth century? Do we have ahead of us another great capital building spurt? Is there something on the landscape, something around the corner that none of us can see that is comparable to the automobile from 1900 on to the present time, with all of the work which was occasioned as the result of that? I don't know, and I always keep reminding myself that in the middle 1870's a lot of people thought we had reached the end. They thought we had finished the great capital building developments, but we hadn't. I don't know what is ahead of us but it looks as if we were not faced with the tremendous capital expansion that we had during the nineteenth century.

Now that is possibly the reason that we haven't found within the last five and six and ten years very much in the way of capital building. We don't need so much in the way of capital building as compared with what we needed even some three decades ago. Then, of course, with population falling off, we aren't needing to build new schoolhouses as we have needed to build new schoolhouses all through our history in the past. And we are not needing to build new homes in the cities, nor more sewers and waterlines as compared with other times in our history, because

the city populations aren't growing now like they grew in the past.

Well, what is the significance of that? Again it seems to me that it is tremendously significant. And why is it significant? Because it means a lack of demand for capital building. It means that the capital building we are going to have will depend upon the inventors and upon the engineers, and not upon population increase. This whole matter is connected with the inequality of income. According to the Brookings Institution in Washington, in 1929 three per cent of the persons in the United States who got income got one-third of all the money income. According to the National Resources Committee, in 1935 and '36, a period of twelve months in there, three per cent of the families in the United States got 21 per cent of all of the dollar income.

I feel that if we are going to keep our economic system going, the men that get money have got to come up and use it. They have got to buy something with it. If you have 100 men and if you have $100 worth of goods put out and if those 100 men are given $100, those hundred men have got to use their hundred dollars in buying that hundred dollars worth of goods. Otherwise, what happens? You won't produce so many goods the next time, will you, because you have goods on hand. Whenever you find people holding onto their money, when you find them leaving it lie idle in checking accounts in the banks, then you find business falling. I don't see any escape from this conclusion.

The more inequality you have, the more likely it is that folks will let their money lie idle in the banks. That is, this high degree of inequality makes it more difficult for the rich person to spend his money promptly. That, of course, is the great difference between business men and college professors. You fellows see that professors like Mr. Moyer and myself get so little that we use it quickly, but you fellows get so much that it is tough on you to try to find ways to use it, and so when you can't find ways to use it, then you just let it lie idle in the bank. The result is unemployment.

Now what about the future? Is there anything that this calls to mind and suggests to us? One thing is the matter of the program of the government in the future. In the past these men who were rich could live very poorly, they could live like the monks of the Middle Ages, but they could use their money in buying another mile of railroad or in buying another factory building, that is, in buying bonds from somebody who would use the money in construction. Now if we are somewhat through with this capital building program, or until something does come along, it seems to me that it is almost necessary, however much we may dislike it, that we keep up a rather liberal program of government spending, or possibly we ought to call it government investment. That means that we need to build good things, of course, and possibly it means that we need to set them up so that they will bring in revenue and enable us to retire these bonds.

Further, in regard to this government spending, let me say to you gentlemen that as I read the record—and some of this I know you won't agree with and will think that I am perfectly crazy—the thing that gave us the prosperity of '34 and '35 and '36 was the big government outlay. The government put out about $3,000,000,000 every year more than it took in. Where did it get it? It created it. The banks created it. The government didn't sell you a bond and keep you from spending the money and then itself spent it. No, that wouldn't help much. What the government did was to turn those bonds over to the banks and the banks made new money of something like $3,000,000,000 a year, and as the result of that, we had the Federal Reserve index going from 58 in the summer of 1932 up to 117 in August, 1937.

Then what happened? Well, business men—and I may say rather frankly business men who think in terms of the nineteenth century—said, "See here, we have got to balance the budget." And there are some folks in Washington wanting to do that now, I understand. So what happened? From the latter part of 1936 on the National Government really had a balanced budget. It took in as much money as it paid out. It stopped creating new money, and then what happened? We had the decline that began in 1937, and it was very sharp.

What have we done since the first of 1938? Well, the government has been spending money again and the debt is now approximately $40,000,000,000. I think that is too bad, It seems to me that the debt ought not to be so big, but keep this in mind, gentlemen. If we can by a program of government spending increase national income from a little more than $60,000,000,000 where it is now back to eighty where it was in 1929, if we can raise it to one hundred where it ought to be in all conscience in relation to where it was in 1929, then with the present taxes we have got we will be taking something more than $8,000,000,000 into the National Government. When

(*Continued on page 22*)

Limestone Screenings and Asphalt Emulsion Stabilizer as Used in the Development of the Park System in New York City[1]

By FREDERICK H. GROSS

Assistant Engineer, Department of Parks, New York City

• **Producers of crushed stone and highway engineers also will find the present paper of much value for it describes the excellent results which have been obtained by the use of a mixture of limestone screenings and emulsion compacted in a relatively thin layer and used as a foundation course in paths, roads and tennis courts. Thousands of square yards of this mixture have been used in the park system of New York City and an excellent market for screenings seems to be offered.**

THE New York City Park system comprises 626 parcels of land covering over 21,000 acres, on which are constructed parks, playgrounds and parkways.

Four years ago, when Park Commissioner Robert Moses, took over this system there were one hundred and nineteen earth surfaced playgrounds and two hundred and eighty parks that were in need of modernization and rehabilitation. Today, there are three hundred and forty modern recreational centers and approximately two hundred of the old parks have been completely rehabilitated and modernized, and several new parkways have been built.

The program to rehabilitate these parks, parkways and playgrounds necessitated various types of construction work. The one feature of this program, that I wish to speak on and I know will be of interest to the crushed stone industry is the type of construction finally adopted for building the walks, playgrounds, roller skating rinks and tennis court areas. Incidentally there might be included in this category the 58 miles of bicycle paths that we are about to construct.

There were several hundred miles of walks and several thousand acres of recreational areas to be constructed in this program. Considerable study was given to the type of surface and base to be used for this work, not only in regard to the original cost of construction and its practicability for playground purposes, but also to include the future maintenance cost.

It was decided that the ideal surface would be a cold asphaltic bituminous pavement of a texture known as fine asphaltic concrete in which all of the stone aggregate passes a ½" mesh. This top surface was laid one and one-half (1½) inches when rolled and to date approximately 300,000 tons have been used as part of the development program. The next step was then to select a base that would be cheap in construction and permanent in character.

Steam cinders thoroughly rolled to a depth of six (6) inches were considered first, due to their low cost. Such a base was not of a permanent character, and in a short time the cost of repairs to maintain this work would far exceed the saving made in the initial constructon, so very little of this type was laid.

Consideration was then given to a cinder concrete base. Several mixes were tried varying from 1 part of cement and 6 parts of cinders to 1 part of cement and 12 parts of cinders. A mix of 1 part of cement to 8 parts of cinders was finally selected which was laid to a depth of five inches. This cinder concrete was laid on a four (4) inch cinder bed.

For the first two years of the construction program this was the typical base used, but several difficulties were encountered. Often the cinders received were not of acceptable quality, and in many cases the surface of this base was very rough which caused the quantity of cold asphaltic concrete used to be far in excess of what should have been required. At this point, I wish to bring to your attention, the fact that one ton of asphaltic concrete as specified by the department should cover thirteen sq. yards of surface but with this base we were seldom able

[1] Presented at the Twenty-Second Annual Convention of the National Crushed Stone Association held at the Netherland Plaza Hotel, Cincinnati, Ohio, January 30, 31 and February 1, 1939.

to obtain more than eleven sq. yards of area per ton of material. Quite frequently the roller rolling the top surface of cold asphalt would crush and disintegrate the cinder concrete base. In many instances cracks developed due to the expansion and contraction of the material.

While this work was in progress investigations

TENNIS COURTS TYPICAL OF THOSE BUILT WITH 3 TO 4 INCHES OF COMPACTED EMULSION STABILIZED SCREENINGS BASE WITH A WEARING SURFACE OF SHEET ASPHALT OR OF ROCK ASPHALT LAID WITHOUT A BINDER COURSE. THESE COURTS ARE USED ALSO FOR ROLLER SKATING AND ARE FLOODED IN WINTER FOR ICE SKATING.

were being conducted with other materials in order to obtain a mixture for the base, that would be as cheap as cinder concrete and at the same time produce better results.

A pre-mixed bituminous macadam base was tried, which was laid to a depth of three (3) inches. The bitumen content of this mix was only 3½% and the stone was mostly of commercial size, ¾" and ⅜", together with a small percentage passing a #40 mesh. This mix was difficult to work. Often picks and pick mattocks had to be used in order to break it up. The cost of it was also slightly higher than the cinder concrete. Several playgrounds were constructed with this type of base, but its use was discontinued for the additional reason that the program was being done in conjunction with the Works Progress Administration and on such work (other things being equal) labor was preferred to equipment. In other words, this type was delivered from asphalt plants at a higher cost than other types made on the job with W. P. A. labor.

Experiments were then tried and test sections laid with several types of emulsions mixed with various aggregates. When these tests were started very little information was available on the subject of stabilized bituminous admixtures. Furthermore, it was necessary for us to confine ourselves to aggregates that could be obtained in the immediate vicinity of New York and that could be purchased at approximately the same cost.

Sand, gravel, various sizes of stone, cinders, slag, limestone screenings, and dolomite screenings were available. These aggregates were mixed sometimes singly and sometimes in conjunction with each other in various proportions, with both weatherproofing and stabilized emulsions. In all these cases the same amount of Asphalt Emulsion was always used.

The first mixes were made at an asphalt plant where a pug mixer was available, and mixed for a period of two (2) minutes. They were then deposited in trucks, hauled five or six miles, dumped and spread to a depth of approximately four (4) inches. During this haulage test, in several instances the emulsion broke completely away from the materials, in some cases the aggregate arrived only partially covered by the emulsion and in only two cases did it arrive in a condition where the aggregate was thoroughly coated with the emulsion, these two being limestone or dolomite screenings when mixed with a stabilizer emulsion. These samples were all rolled the same day with a 300 lb. water

DUMPING EMULSION STABILIZED SCREENINGS ON SUBGRADE. THERE IS NO ADHESION OF THE PARTICLES UNTIL AFTER THE WATER HAS DRIED OUT FROM THE MIXTURE.

roller. After seven days it was found that the one that would be acceptable as a base was the limestone or dolomite screenings, mixed with a stabilized emulsion, the others had all broken apart.

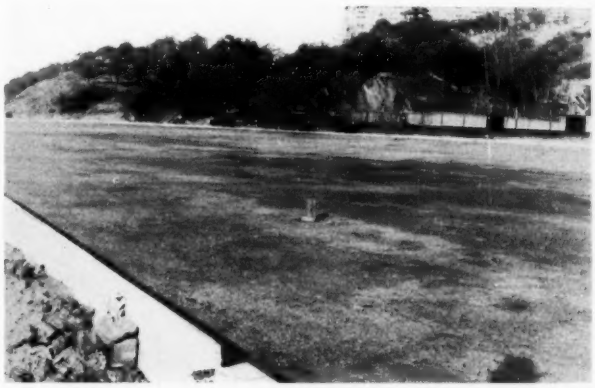
As previously mentioned, this program was carried out with the W. P. A. labor and it was therefore

more suitable to mix this material at each individual job. To hire pugmill mixers was not only costly but it was difficult to obtain them. Seven "S" concrete mixers were available on the W. P. A. construction jobs and the same mixes were again tried as had been put through the pugmill. The same results were obtained except that in all cases when the weatherproof emulsions were used the material all balled up in the mixer.

These experiments proved that a mixture of limestone or dolomite screenings with a stabilized emulsion would provide the best base for our work. The next problem was then to determine, the gradation of screenings which would result in the maximum density, the correct percentage of stabilized emulsion the ideal amount of water to add to the mix and the minimum depth that the resulting mixture should be placed. These factors were all necessary in order to obtain the ideal mix at the cheapest cost. Here again we had no previous work of this kind to act as a precedent in determining these proportions. However, Mr. A. T. Goldbeck, Engineering Director of your organization and Mr. C. L. McKesson, Director of the American Bitumuls Company had previously made extensive laboratory tests with similar materials. The data obtained from these experiments were considerable aid to us in determining the proportions to use. In all our work we have found that to obtain the best mixture it is necessary that the screenings have a sufficient amount of fines passing a 200 mesh sieve and that a sufficient amount of the proper quality of emulsified asphalt stabilizer be used.

PATH MADE WITH STABILIZED SCREENINGS TO BE COVERED WITH A BITUMINOUS MIXTURE WEARING SURFACE

The quarries adjacent to New York City had several natural gradations of screenings available. There were two types of the following gradations that were used; one being a red limestone screening of which 100% passes a ½ inch screen, 20% to 40% passes a 20 mesh, and 5% to 15% passes a #200 mesh; the other was a white limestone screening of which 100% passes a #4 mesh, 40% to 60% passes a #20 mesh, 25% to 40% passes a #100 mesh, and 15% to 25% passes a #200 mesh. It was found that either of these gradations was suitable for this type of base, but the department preferred the red limestone screenings, the white producing too smooth a surface finish. These were mixed with several types of emulsion stabilizer in the proportions of 0.4 gallons, ½ gallon and 2/3 gallons per cubic foot of material. Water was added varying from ¼ gallon to ¾ gallon per cubic foot of material, depending upon the moisture of the screenings. The mixes were laid to a depth of three, four and five inches when rolled.



A LARGE EXPANSE OF STABILIZED EMULSION SCREENINGS BASE UPON WHICH A WEARING SURFACE WILL LATER BE PLACED.

The results of these tests showed (1) a depth of four inches loose or three inches when rolled was the ideal thickness for the base (2) sixteen gallons of asphalt emulsion stabilizer per cubic yard of screenings, together with approximately six gallons of water produced the best mixture and (3) limestone screenings of the following gradation 100% passing a "½" screen, 20% to 40% passing a #20 mesh, 5% to 15% passing a #200 mesh produced a mixture of suitable density.

The specifications adopted for laying this base are as follows:

After the subgrade is thoroughly rolled and compacted a base should be laid, consisting of limestone

screenings and an asphalt stabilizer four inches loose, then rolled and compacted:

The limestone screenings shall be placed in a concrete or pugmill mixer then add the stabilized emulsion at the rate of 16 gallons per cubic yard of limestone screenings with sufficient water so that the

ASPHALT BLOCK WEARING SURFACE LAID ON EMULSION STABILIZED STONE SCREENINGS

mixture will come up and quake when deposited in place, but not enough to cause it to flow. The time of mixing shall not be less than one minute.

After the emulsion and limestone screenings have been thoroughly mixed they shall be spread upon the compacted foundation and then screeded off to thickness of 4". As soon as the emulsion and screenings have set up they shall be rolled with a hand roller. The time required before the hand rolling shall take place depends entirely upon the temperature and will have to be determined on the job. In hot weather the hand rolling can be done in about 2 to 3 hours, after the spreading but in cooler weather it may be necessary to wait longer. Approximately 24 hours after the base has been laid it may be rolled again this time using either a 2½ or 5 ton tandem roller with water attachment. Again the temperature is the governing factor, as on a hot day it will stand rolling with a 5 ton roller 24 hours after being laid, whereas on a cool day a 2½ ton roller should be applied 24 hours after laying and then the 5 ton roller the following day.

The only objection to this type of base is the difficulty encountered while laying it during the cold winter months. The asphalt emulsion freezes when left in the open and any mix made under a temperature of 32° F. does not set and will not set until the water has evaporated.

To overcome this difficulty, experiments were made with a vacuum processed machine. This machine successfully extracted the water out of the mixture in the area laid and within one hour after being put down, it was rolled by a 1½ ton roller. Furthermore, there was no asphalt extracted, the water being very clear. During this process the mixture was also compacted, as the roller produced very little additional compaction. Up to the present time there are no signs of any damage being done to the base through this operation.

With the aid of this machine, work of this type can be carried on during the winter months, at an additional cost, the price varying between $.06 and $.10 per square yard, depending upon the amount of work done. The cost of the materials to lay this base to a depth of three (3) inches when rolled is thirty-six ($0.36) cents per sq. yard or twelve ($0.12) cents per inch of depth per sq. yd.

There were several places where this base was subjected to heavy truck loads for a period of several months. These trucks were loaded with sand, cement, stone, lumber and asphalt and weighed between 15 and 20 tons.

Since the base did not fail under these loads, it was decided to use the same depth as a base for a 600 ft. long service road leading to one of our garages. This road surfaced with 1½" of Fine Asphaltic Concrete, was constructed over a year ago and is in excellent condition today.

The department, during the past year, awarded several contracts that included thousands of yards of this base. The contractors supplied the mix either through 1 yard paving mixers mixed on the site of the work or through Transit Mix Machines transporting the mix from a central storage plant. Both of those methods proved successful and the cost of furnishing and laying this base, 4 inches deep, was less than $0.70 per sq. yard.

The excellent results obtained by the Park Department during the past four years with the stabilized aggregate base lead me to believe that a better, more stable and longer lived road can be built for less money than we have, in the past, been obliged to pay for roads of lesser quality.

Future Highway Development as Related to the Crushed Stone Industry[1]

By MERTON R. KEEFE

Chief Engineer, State Highway Commission of Indiana, Indianapolis, Indiana

• **The State of Indiana in common with other States is faced with the problem of bringing its highway system up to a physical condition which will make it adequate for carrying with safety and economy a rapidly expanding and ever growing traffic. Obsolescence and high maintenance costs of highways must be overcome. Mr. Keefe shows how he is solving the highway problems in his State by making intelligent use of research.**

THIS paper must necessarily express only the views of one person connected with the State Highway Department of Indiana and is predicated on the conditions that are found in that one state.

The Highway System of Indiana comprises 10,000 miles of road of which 4200 are concrete, 4600 are bituminous type and 1200 traffic bound and other types.

Many miles of our system are badly in need of widening and resurfacing to care adequately for the traffic which is using these roads, as well as to reduce the resulting high maintenance costs from poor surfaces. When highway departments were established in the different states and intensive promotion of good roads began, many of the roads were built to widths as low as sixteen feet. No one foresaw the growth of the automobiles use nor could any engineer in highway work at that time have forecast the development of automotive transportation from the Model T with its twenty-five mile speed to the present day car with its one hundred mile speed or the one ton truck to the twenty ton truck and trailer of today.

Obsolescence has come to our roads practically over night. When we started building roads eighteen feet in width with five foot shoulders, all the highway engineers felt they were building the last word in highways. Fully eighty-five per cent of the Highway System of Indiana have traveling surfaces of eighteen feet or less and accident rates on these highways with the increased traffic and speeds make us wonder what we are going to do to modernize these roads so that the traffic can move in an orderly and safe manner. For speed, we must consider in our designs on new construction as well as reconstruction of these highways. It is here to stay and must be one of our serious considerations.

What to do with this eighty-five per cent of our road mileage is a serious problem. There are certain interests who would have you tear up and throw away a large part of this mileage and rebuild it with 22 foot wide traveling surfaces. These interests forget the costs to the state and show little foresight or rather ignore the financial situation in which the state finds itself.

We have at present approximately 1500 miles of eighteen foot roads carrying daily traffic of 2000 or more, 20 to 30 per cent of which are trucks. Shall we tear up and throw them away or reconstruct them using the present traveling surface as a foundation for another wearing surface? To junk these roads and rebuild them would cost our state approximately $50,000,000. This we cannot afford to do. The foundation value of a road which has been in service for ten or twelve years is invaluable. We cannot build one as good, try as we may.

This mileage of roads must be widened to 22 feet by the use of waterbound base courses or black base courses, preferably plant mix and the full new width treated with a leveling course and new wearing surface. I am convinced by our own experience that the small additional cost of plant mix over road mixes or mixed in place will pay good dividends in Indiana. Prices have, at times, been too high on plant mix but if a policy was well established of using it rather than mixed in place these prices we feel would come within the ranges of economy.

The highway engineer has, through experience, developed the fact that a two lane road of adequate width should carry up to 5,000 vehicles per day, 15 to 20 per cent of which traffic may be trucks.

[1] Presented at the Twenty-Second Annual Convention of the National Crushed Stone Association held at the Netherland Plaza Hotel, Cincinnati, Ohio, January 30, 31 and February 1, 1939.

Based on these figures, the Bureau of Public Roads estimates that not more than five per cent of the road mileage of the United States need ever be more than an adequate two lane road. In our state it is very doubtful if traffic development will require even this amount of three or four lane roads. Therefore, we must look to the widening and resurfacing of the eighteen foot roads in our state. Our accident records show that our road widths are a serious hazard and must receive our close consideration. Try as they may our maintenance department is unable to maintain the shoulders adjacent to the pavement edges on account of the suction of dual tires on trucks and buses which necessarily must have a part of the outside tire overhang the pavement edge when passing other vehicles.

The maintenance department had for several years previous to 1936 contended that the use of 100 per cent crushed material for surface treatment work would help solve the surface treatment costs with which this department had to contend. Pressure on the commission by some interests prevented the adoption of a specification beyond requiring 35 per cent of crushed material. After a year's application of this specification we went to one requiring 100 per cent crushed material for surface treating aggregate and required that each piece of the material must show at least two broken faces.

Since the adoption of this 100 per cent crushed specification we are getting better cohesion of aggregates in this type of surface, as well as getting a more non skid surface and less raveling. Where five years ago our highway system was plastered with "Slippery when wet" signs, few today remain and we feel that an indefensible condition has been eliminated.

In 1936 our Highway Commission joined Purdue University in establishing a research department at the university which is administered by an Advisory Board composed of eight members, four from the university and four from the State Highway Commission.

One of the first problems studied was the surface treating work which was being done on our state highways. Surface samples were taken from the pavement at the time surface treating was done and periodically thereafter and much valuable information has already been developed on stripping of bituminous material from the different type aggregates used as well as degradation of the aggregates under the roller and under traffic.

Coating of aggregates by dipping and drainage method was first studied in the wash tests and they are now engaged in another series of tests, coating the aggregates in a pug mill reproducing plant mix conditions. Similar wash tests for adhesion of bitumen to aggregates are being run on the pug mill samples.

Adhesion of the bitumen to aggregate is only one of the phases being studied on the surface treating problem. Cohesion studies of the bituminous coated aggregates is now under way and we hope to develop information by our wash tests and cohesion tests that will be of great value in the use of this class of bituminous surfaces.

Further studies being conducted at Purdue University will be touched on later.

Since the beginning of development of the State Highway System, the roads have been built without much thought being given to the foundation or subgrade conditions. Only within the last few years has the highway engineer begun to give serious thought to the load carrying properties of the subgrade. This was first brought about by the curling at joints of concrete pavements. Investigation to determine the causes for such curling developed the need for subgrade stabilization. Only in the last five years have we established a soils department in our organization and even up to this time we have done very little to improve subgrade conditions. It has been a difficult matter to convince our commission that the added expense of subgrade treatment will pay dividends in the added life given to all types of pavement.

To contribute more practical knowledge to stabilization of subgrades and cheap type surface courses on county roads which may also be used as base courses on low traffic roads of the state system, we have built at Purdue University two test roads.

The first of these roads was built in the summer of 1937 and is now going through its second winter of observation. Daily observations are made on heaving of the ten different types of stabilized sections, moisture content is taken at fixed intervals as well as a daily temperature record kept. This test section was built ten feet in width and the first winter's observations were made with half the width of the stabilized sections covered with two inches of loose gravel, while the other half had no covering.

The second test section was built in the summer of 1938 and consists of twelve test sections, 20 feet wide and each 50 feet long. The road was graded and drained to a standard roadway width of 36 feet, the subgrade being of clay.

The first two sections are cement soil stabilized,

using different percentages of cement in each of the two sections.

The next two sections are aggregate clay mixture stabilized with Na.Cl. and Ca.Cl.

Four sections are clay, aggregate, stabilized with variable proportions of soil while the remaining four are aggregate, clay bituminous stabilized sections.

These sections were selected after the previous year's experience on the first test road and were built and are being studied as base courses, which might also serve as a cheap low cost county road.

Truck traffic was run over all the sections this last fall and records of wear and performance were carefully noted. Winter observations on temperature, heaving and moisture were taken daily up to the present time.

In the laboratory freezing and thawing tests are being carried out on compacted cylinders of materials mixed in the same proportions as the field test road sections.

This research should develop much information as to economical subgrade treatments as well as furnishing information as to traffic loads these sections will carry.

All this research work should be of benefit to this aggregate producers group.

When some five years ago our specifications were changed to require the use of divided aggregates in concrete work, we were able to drop our cement content so that an appreciable saving was effected. In some parts of Indiana the gravel producers were unable to furnish the upper limit sizes which benefited the crushed stone producers who were called upon for these sizes. This change in specifications materially benefited the state in the costs of rigid pavements, although we found our beam strengths and compressive strengths equal to or higher than before.

The secondary or farm to market program initiated by the grants from the Federal Government two years ago has broadened the field for crushed material in road construction by the state highway department.

In our state the Highway Commission is matching the Federal Funds for the counties since our County Highway Departments are unable to financially take advantage of these grants. The type of road being built is naturally slightly higher than county standards as the commission engineers design with a view of maintenance costs so that the counties will not be burdened with too much of a maintenance load.

Our 1938 farm to market road construction program is practically all under contract and we are much encouraged by the fact that some of our contracts have been let for waterbound roads as cheap as for traffic bound surfaces. Naturally most of these county roads are low in traffic count and require less surface thickness than the roads on the state system. A waterbound road with a bituminous seal as a first step of stage construction is sufficient to carry the traffic offered.

Although the allotment for farm to market roads has been cut by the Federal Government for the fiscal year of 1940 and 1941, we are of the opinion that these grants will not be discontinued but rather will be increased in future years. There has been introduced a bill, in the present Congress, to allocate 50 per cent of all Federal Aid grants to the building of farm to market roads, which indicates the broad interest of our motorist in this class of construction.

In Indiana we feel that the regulations issued by the Bureau of Public Roads for the first farm to market road grants were not adapted to our state, in the requirement which specified that the monies allocated must be spent in 50 per cent of our counties. Our State Wide Traffic Survey showed we have 66,600 miles of county roads and that 76 per cent of this mileage had an all weather surface. The other 24 per cent are still in the mud and it is our feeling that a better showing would have resulted by using the funds for building roads to farmers, whose children are deprived of school attendance in certain months of the year and the families are being left without mail delivery and access to their trading centers due to impassable road conditions.

It is our hope that when the regulations are issued for the expenditures in the fiscal years of 1940 and 1941 that such 50 per cent provision will have been eliminated. If this is done we will be able to spend these funds to the betterment of road conditions for those who are forgotten in the mud and your industry will be benefited in the furnishing of aggregates for such construction where no surface now exists.

Requirement of spreading the work in 50 per cent of our counties has resulted in going into counties and rebuilding good all weather roads by widening shoulders and placing an oil mat on roads carrying less than 100 vehicles per day. Expenditure for this type of improvement is merely taking the farmer out of the dust and not out of the mud.

The 1937 session of the Indiana State Legislature passed a law requiring the State Highway Commission to take over the maintenance of all the streets, over which state highways are routed in cities of

3500 population or more except the streets of the city of Indianapolis. The law also required the increase of the system by 500 miles before January 1, 1938, and a like amount before January 1, 1939. This, therefore, increased the highway system mileage 1,000 miles in two years.

Already a strong demand is being made by the local motorist for the reconstruction of these county roads taken in and on account of the high maintenance costs, construction will have to be undertaken as fast as funds can be found to carry out the work.

A large percentage of these roads have a traffic bound stone or gravel surface, which shows an average thickness of but three inches which will withstand but little freezing and heaving. In most cases the gravel used is dipped material, too fine to withstand much traffic without heavy losses of materials.

A large part of these roads will require additional base courses and bituminous surface courses as soon as funds can be found to start this improvement.

Indiana has constructed during the past three years, on secondary roads, approximately fifty miles of clay, gravel, chemical, stabilized base courses which were covered with bituminous wearing surfaces.

The prices bid for this class of material were practically the same as prices bid on other projects for waterbound base courses of equal thickness. This type of base course has been disappointing in other respects and no more designs of this material are being contemplated at this time.

A large part of the mileage of city streets taken into the system are badly in need of attention due to the lack of any improvement during the depression, and a serious lack of maintenance. Much surfacing with bituminous aggregate mixed is required at once.

I have tried in my foregoing remarks to give you a summary of necessary work required to modernize our present highway system so that it will meet the increased traffic needs and allow you to draw your own conclusion as to the future of your industry in our state.

Discussion of construction of divided lane roads has been only touched upon but this subject alone requires much study and collection of extensive data to properly forecast future development along these lines.

Only last week at the Purdue Road School we listened to a very fine discourse on highway safety and some of the requirements necessary to accomplish safe travel on the highways. The speaker stated that if in 1910 one had predicted that in 1938 there would be thirty-eight million cars on our highways he would have been considered a fit person to be put away in an asylum for the insane.

This speaker, who is connected with the automotive industry, stated that in less than ten years we would be driving cars weighing 1800 pounds instead of 4000 pounds and these cars will be manufactured to sell at approximately half the price we are today paying. That thirty-eight million cars is not the top limit on car owners, but it will reach to fifty million in that length of time.

With this increased traffic and lowered accident rates, which must be accomplished, more divided lane roads will be demanded and modernization of present state highway systems become a necessity.

The future of the highway industry is assured by these requirements.

What Lies Ahead for Business

(*Continued from page 14*)

we do that we can balance the budget and begin paying off the debt.

Undoubtedly we have got to have government expenditures to take us out of these depressions, and then when we get prosperous we have got to let the Federal Government tax us heavily enough so that we can pay off the debt and get ready for extending it again when we get into the next depression.

We are thus faced with new problems and I wish I knew the answers to them, but I don't. What we have got to do is to feel our way along as best we can, but let me emphasize again that we do seem to be in a new world. We do seem to be in a condition where we are not expanding so rapidly and that brings us face to face with new problems. One thing that would help us, to repeat, is a reduction in the equality in income. I feel that business men really ought to adopt a self-denying ordinance and say to themselves and their brothers, we are not going to let ourselves have more than $100,000 a year, or whatever it is that you fellows get, because when large incomes are received it is difficult to use them promptly. When they are not used promptly unemployment results and then the only possible answer, it seems to me, is to do something by way of attempting to get business started again through government expenditure.

The Pennsylvania Turnpike[1]

By SAMUEL W. MARSHALL

Chief Engineer, Pennsylvania Turnpike Commission, Harrisburg, Pa.

• **Toll roads have passed almost out of existence in the United States, but of late years there has been some indication that they may return for special purposes. The Pennsylvania Turnpike, unusually well described in the present paper, is an extremely interesting example of a toll road, now being built for high speed traffic through the mountains of Pennsylvania from Harrisburg to Pittsburgh. This road may be a forerunner of more roads of this type and hence has unusual interest.**

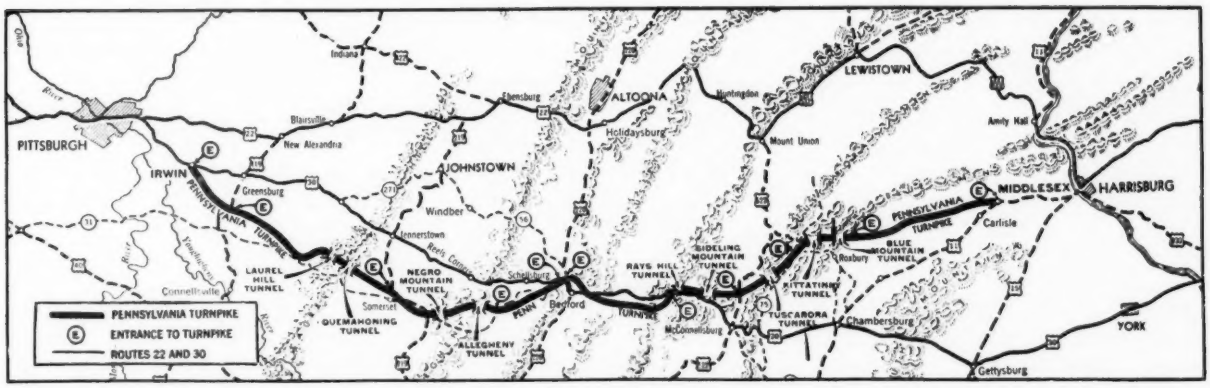
MUCH has been written and much has been said about super-highway proposals in this country. The idea has gripped the imagination of newspaper feature writers and the public has read of a number of proposals to criss-cross the country with a network of super-highways. Not only would such highways greatly expand our Nation's commerce but they would go far toward solving the unemployment problem.

The super-highway idea has come up for widespread discussion in the state of Pennsylvania. But we, I am proud to say, are not merely theorizing on the merits of such a route; we now are actually building one. I refer to the Pennsylvania Turnpike which will connect the state capital at Harrisburg with the great Pittsburgh industrial center. This project is the greatest single highway job ever undertaken in the history of our Nation—and we predict that it will be the first link in a national network of super-highways.

For the benefit of those of you who may not be acquainted with this project, I would like to describe briefly some of the details and interesting highlights. A four-lane, divided highway will be built for a distance of 160 miles. The route will utilize seven tunnels and most of the roadbed of a railroad that was never built—the old South Penn Railroad abandoned more than 50 years ago after an expenditure of some $10,000,000. Use of the tunnels will permit a low-grade route without the towering grades and curves of existing highways across the Appalachian Mountains. The maximum ascending grade will be three per cent; curves will be long and sweeping with minimum radius of about 1,000 feet. Traffic will move in opposite directions separated by not less than 10-foot parkway. There will be no intersecting crossroads or railroad grade crossings. Cloverleaf type of connections will be built for side roads.

The turnpike, definitely a public necessity, will make possible monetary savings to all vehicles, principally trucks. Comfort and convenience not now possible on existing routes will be provided. The route will relieve present congestion on Pennsylvania's existing east-west highways which in 1937 were used by approximately 3,500,000 vehicles.

[1] Presented at the Twenty-Second Annual Convention of the National Crushed Stone Association held at the Netherland Plaza Hotel, Cincinnati, Ohio, January 30, 31 and February 1, 1939.



PENNSYLVANIA TURNPIKE IN RELATION TO PRINCIPAL EXISTING HIGHWAY ROUTES BETWEEN PITTSBURGH AND HARRISBURG

This great contribution to Pennsylvania's progress is being provided without any cost whatsoever to the state government. For this, the commonwealth can thank Walter A. Jones, Pittsburgh and Washington industrialist, who as chairman of the Pennsylvania Turnpike Commission, aroused the interest

WEST PORTAL AND WEST APPROACH CUT OF BLUE MOUNTAIN TUNNEL, FROM SIDE OF CUT LOOKING EAST

of President Roosevelt, Secretary of Interior Harold Ickes, and Chairman Jesse Jones of the R. F. C., in the project. Mr. Jones induced them to work out this financing arrangement: the PWA made an outright grant of $26,100,000 and the R. F. C. agreed to buy the commission's bonds in an amount not exceeding $35,000,000. The bonds, paying three and three-quarter per cent interest, will be amortized over a long period of years by tolls to be collected from users of the highway. Then the highway will revert to the state free of toll.

As motorists you might be expected to have some interest in the general aspects of the Pennsylvania Turnpike, but as crushed stone producers you are much more vitally interested in its direct effect upon the prosperity of your industry.

While our plans are still subject to change in minor details, I am able to estimate that the gross amount of crushed aggregate used will be approximately 1,800,000 tons. The specifications set up for the various grades and kinds of this material will conform closely to the specifications enforced by the Pennsylvania Department of Highways.

Stone used in the construction of the highway will be purchased by individual contractors from approved quarries, many of which no doubt will be along or near our right-of-way through the southern counties of Pennsylvania. Many quarries able to furnish high grade lime and sandstones are within easy reach of the operation, but their capacities are likely to fall short of our demands, and no doubt other quarries throughout the state will do a substantial business with our contractors.

Coarse aggregate will be used in nearly every phase of our construction work—for our base course in some places; for our concrete surfaces; for class A concrete in bridges and tunnels; for class B or mass concrete; for pipes and drains, for culverts, for rubble masonry, and even for concrete piles in a few places. In a word, the Pennsylvania Turnpike will provide a steady market for crushed stone from the pouring of our first concrete a few weeks ago until the job is finished in 1940.

I can best show what this will mean to the crushed stone producers by comparison with consumption on other big jobs, and by comparison with the output capacity of our Pennsylvania quarries. Last year the Pennsylvania Department of Highways, one of the Nation's heaviest buyers, used approximately 7,300,000 tons of coarse aggregate, only four times the amount we will use on the Turnpike alone. Then again, Pennsylvania's annual output of crushed stone used in concrete and in road-building is between six and seven and a half million tons, which means that we will use a substantial part of the Pennsylvania Industry's production on the Turnpike alone. Owing to our heavy demands on Pennsylvania quarries, there will likely be temporary new markets for quarries in other states, so that the industry in several states will in all probability benefit through our project.

Then again the cement industry, in which Pennsylvania leads the nation, will find one of its best markets in years in the Pennsylvania Turnpike. We expect to use in tunnels and roadway at least 1,500,000 barrels of cement, a little less than 1-20th the total output of Pennsylvania's cement plants.

For those of you who produce sand at your plants, I can report that we expect to use at least 600,000 tons of sand, or an even higher proportion of Pennsylvania's annual production.

The steel industry, too, will benefit by our purchase of about 20,000 tons of steel for reinforcing in bridges, tunnels, and elsewhere.

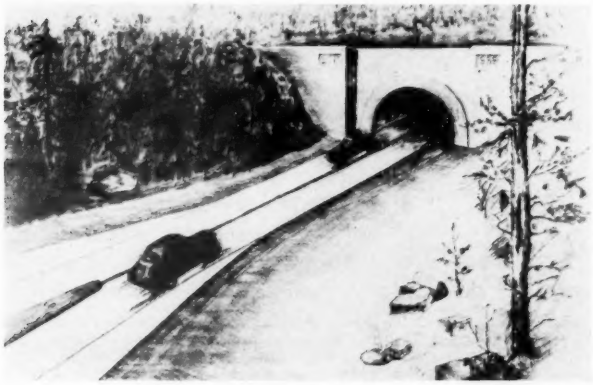
From these few figures, you can see that the Penn-

sylvania Turnpike will be a major factor in the business and industrial picture for 1939 and 1940.

In addition to the 25,000 or more workmen to be employed indirectly in furnishing supplies and materials to the contractors, at least 10,000 men will be employed directly on the project by fall of this year. They will be paid good wages by private employers, which in turn will stimulate other lines of business throughout the state and elsewhere.

Thus far I have tried to give you a picture of what one super-highway project will do for your industry in particular and for the industry and business life of the nation at large.

Now I ask you to consider with me what extension of this Turnpike across the nation would do to restore genuine prosperity! Already we are drawing plans for extension of our road 112 miles from Harrisburg to Philadelphia; but our Chairman is not content with this. Mr. Jones envisions a nationwide system of super-highways criss-crossing the country east and west and north and south. His plan, however, would be financed entirely by private capital, costing the taxpayers nothing. In a recent feature article in the *Washington Herald-Times*, Mr. Jones was quoted as saying: "Pennsylvania points the way to a practical solution of the unemployment problem.



ARTIST'S CONCEPTION OF ENTRANCE TO BLUE MOUNTAIN TUNNEL

"Construction of a national network of super-highways on terms similar to those worked out between our Turnpike Commission and the R. F. C. and PWA would employ literally millions of men without strain on the Federal Treasury or on the various states. . . .

. . ."The Government would actually be lending only its credit, and the national debt would not be increased . . . and the needed workmen would be hired by private contractors. . .

"I propose creation of a Federal authority with power to co-operate with the various states in financ-

WEST PORTAL OF BLUE MOUNTAIN TUNNEL FROM EAST PORTAL OF KITTATINNY

ing and constructing a carefully planned system of super-highways to serve the nation and to put people to work.

"I propose that this work be financed by sale of Government-guaranteed bonds, to be amortized over a period of years by tolls low enough to attract the volume of traffic required."

When this article appeared, United States Senator James J. Davis was so impressed by the possibilities outlined that he read the entire two-column article into the Congressional Record. We hope that some action on this proposal will be taken at this session of Congress.

Some indications of the way this national turnpike system would restore prosperity have already appeared along the turnpike in Pennsylvania. Mild booms have been reported from towns along the right-of-way where construction is already under way, and other towns have benefitted for over a year by establishment of district headquarters there. This trend will be extended from town to town as new contracts are let, until the whole region through which our road passes has been permanently benefitted. This is no isolated case of prosperity following a new road; it always has been so, and always will be so.

As business men I know you appreciate the fact that progress has always followed the development of transportation facilities—the building of new roads, canals, railroads.

Every business man of today has seen how real-estate advances in value, how new communities spring along the highways we have been building in recent years. This has always been true, and will be true in the future.

Every patriotic American familiar with the dramatic story of the settlement of the Nation knows how the pioneers were dependent upon the early toll roads, and later the canals and railroads.

Over the old Lancaster Turnpike, opened 150 years ago, flowed an unending stream of pioneers and immigrants on their way from Philadelphia to settle the inland areas of our State and Nation. The old Cumberland toll road was another major factor in the westward march of empire.

Then again it is a matter of historical record that the construction of the Erie Canal through New York State in the beginning of the last century advanced that State's commerce so rapidly that Pennsylvania was forced to build its own canal to meet the competition.

Every student of American history knows, too, how civilization followed the railroads as they advanced across the continent 60 years ago, and how in our own day highways are the arteries along which commerce and business flow.

In exactly the same way, prosperity and progress will follow the construction of the Pennsylvania Turnpike now under way through some sections of Pennsylvania not now fully developed.

The Pennsylvania Turnpike will bring permanent gains in population and business to this Commonwealth—and this will be in addition to its service in providing employment in this time of need, and to its military value.

While on the subject of history, I might venture to remind you that each of those early transportation facilities—the toll roads, the canals, and the railroads—was violently opposed by reactionary elements of the times. Such elements jeered at the steam boat, the steam locomotive, and the airplane. But history has proved no one can stand in the way of progress. And super-highways are the next step in America's progress.

Skid Resistance of Road Surfaces

(*Continued from page 9*)

face can be definitely determined is by an actual road test at various speeds, using equipment of the general type used in our studies. In the state of Oregon, in New York City and in St. Louis, such equipment has been built and tests have been conducted. The writer recommends that all State highway departments and city street departments conduct tests along these lines and eliminate the surfaces which the tests indicate to be slippery.

The writer has been informed on various occasions that the men who furnish the materials in highway construction are a respected and influential group. It would seem quite proper that materials men should do all that they can to promote the construction and maintenance of safe highways and particularly safe road surfaces. With the above facts before you, I charge you with the responsibility of aiding in bringing this about. In closing I desire to offer the following summary in regard to our tests.

Summary

In this report, the writer has attempted to explain why road surfaces are slippery and has suggested remedies for correcting this condition. In our driving tests on curves, in the braking tests, and in our observations of traffic, we have found that the margin of safety when driving at the high speeds of traffic today is small, even on dry surfaces where high coefficients are available. Accordingly, the engineer should make every effort to build the maximum possible amount of skid-resistance into all road surfaces. He should not build surfaces or permit surfaces to develop a polished or glazed surface condition. He should make every effort to maintain a surface with a "sandpaper" finish, or with a smooth gritty finish in which hard abrasive aggregate is securely held in place by a somewhat softer cementing medium. The ideal skid-resistant surface is one in which this gritty surface condition is continually renewable under the action of traffic. With our present knowledge of the causes of slippery surfaces and the remedies to prevent slipperiness, construction and maintenance departments should now be able to develop construction and maintenance standards which will insure that every mile of road is skid-resistant. When this is brought about, "slippery when wet" signs will disappear from our streets and highways and another milestone in traffic safety will have been passed.

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